A Review of the *U.S. IOOS Coastal and Ocean Modeling Testbed*: Inter-Model Evaluation of Astronomical Tides, Hurricane Storm Surge, Coastal Inundation, and Wind-Waves in the Gulf of Mexico

Patrick Corbitt Kerr, A. Donahue, J.J. Westerink, Univ. Notre Dame
R.A. Luettich, Univ. North Carolina at Chapel Hill
L. Zheng, Y. Huang, R.H. Weisberg, Univ. South Florida
H. Wang, Y-C. Teng, D. Forrest, J. Zhang, VIMS
A.T. Haase, A. Taylor, A Kramer, Meteorological Development Laboratory, NOAA
J. Rhome, National Hurricane Center, NWS
Jesse Feyen, Coastal Survey Development Laboratory, NOAA
E. Smith, G. Crane, Southeastern Universities Research Association
B. Baltes, Integrated Ocean Observing Systems Program, NOAA
Numerous Other Contributors

April 3, 2013
4th NOAA Testbed & Proving Ground Workshop

Models

ADCIRC (SWAN + ADCIRC)

Finite Element, Explicit Time Stepping,
(Waves Tightly Coupled)

FVCOM (SWAN-FVCOM)

Finite Volume, Explicit Runga-Kutta Time Stepping,
(Waves Loosely Coupled)

SELFE (WWMII+SELFE)

Finite Element, Implicit Time Stepping,
(Waves Tightly Coupled)

Unstructured Grid

Models

ADCIRC (SWAN + ADCIRC)

Finite Element, Explicit Time Stepping,
(Waves Tightly Coupled)

FVCOM (SWAN-FVCOM)

Finite Volume, Explicit Runga-Kutta Time Stepping,
(Waves Loosely Coupled)

SELFE (WWMII+SELFE)

Finite Element, Implicit Time Stepping,
(Waves Tightly Coupled)

Unstructured Grid

SLOSH

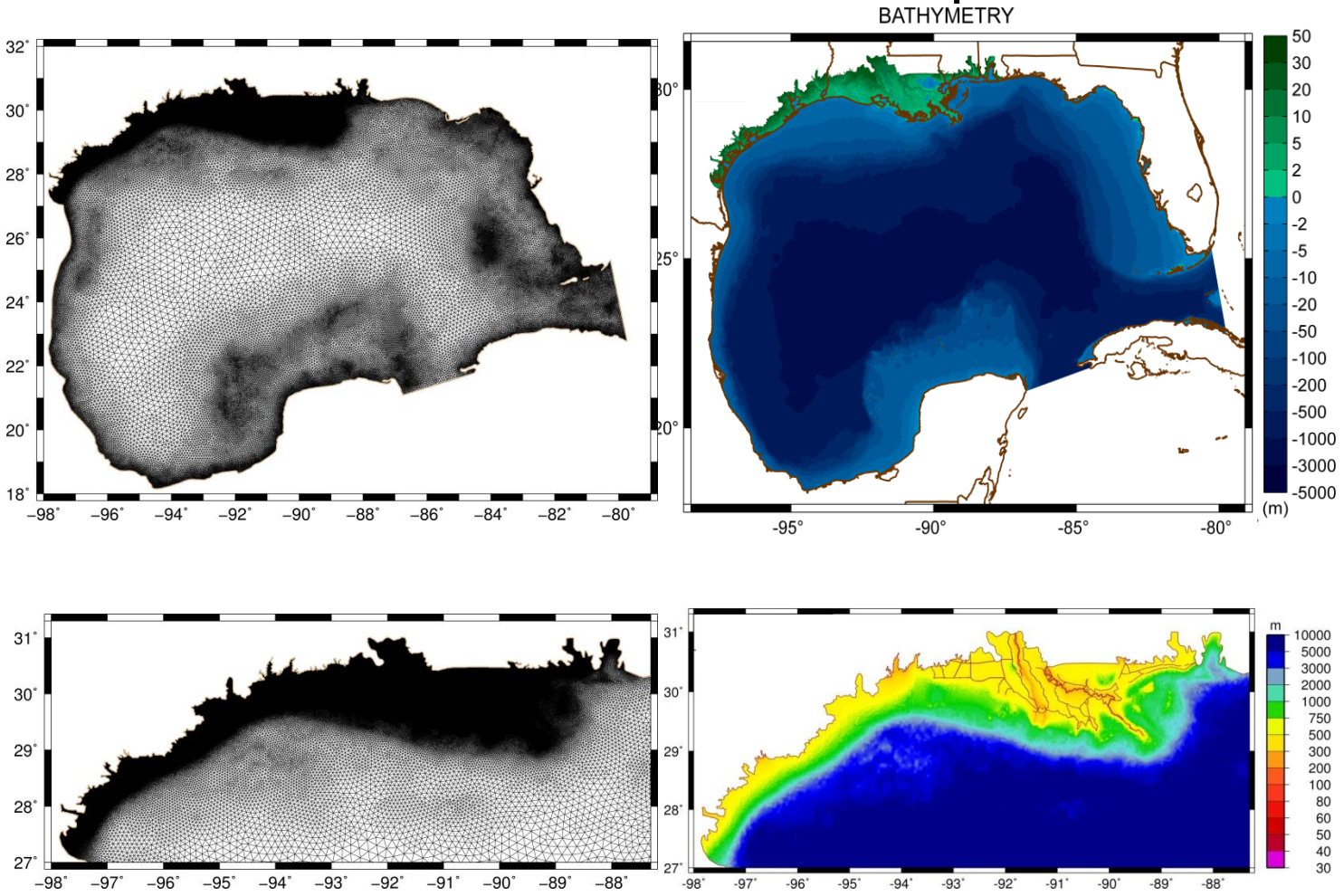
Finite Difference, Explicit Time Stepping
No Waves, Tides added on

Structured, Deformed Grid

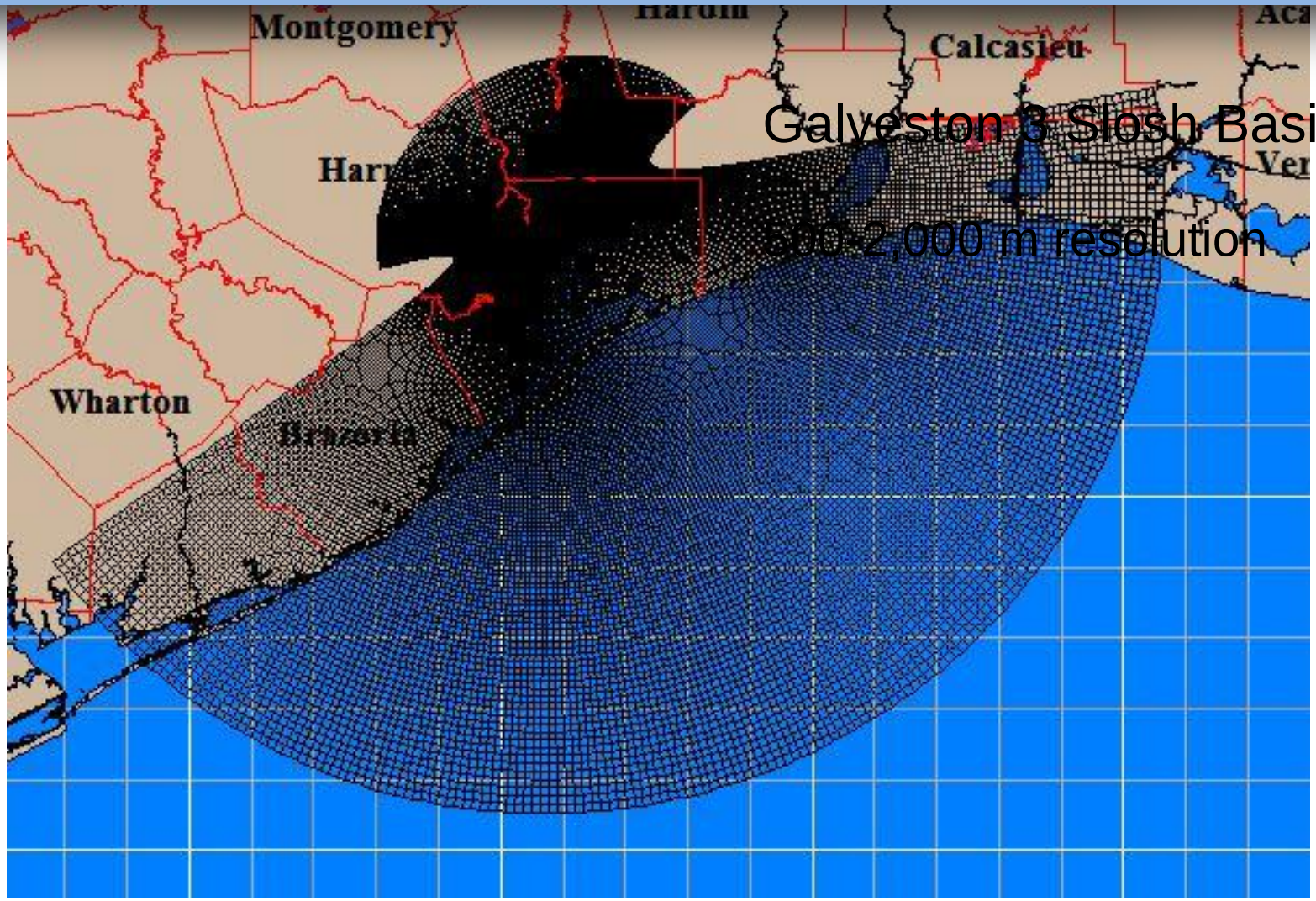
Gulf of Mexico Unstructured Grid

“Ultra-lite” Grid for Inter-model Comparisons

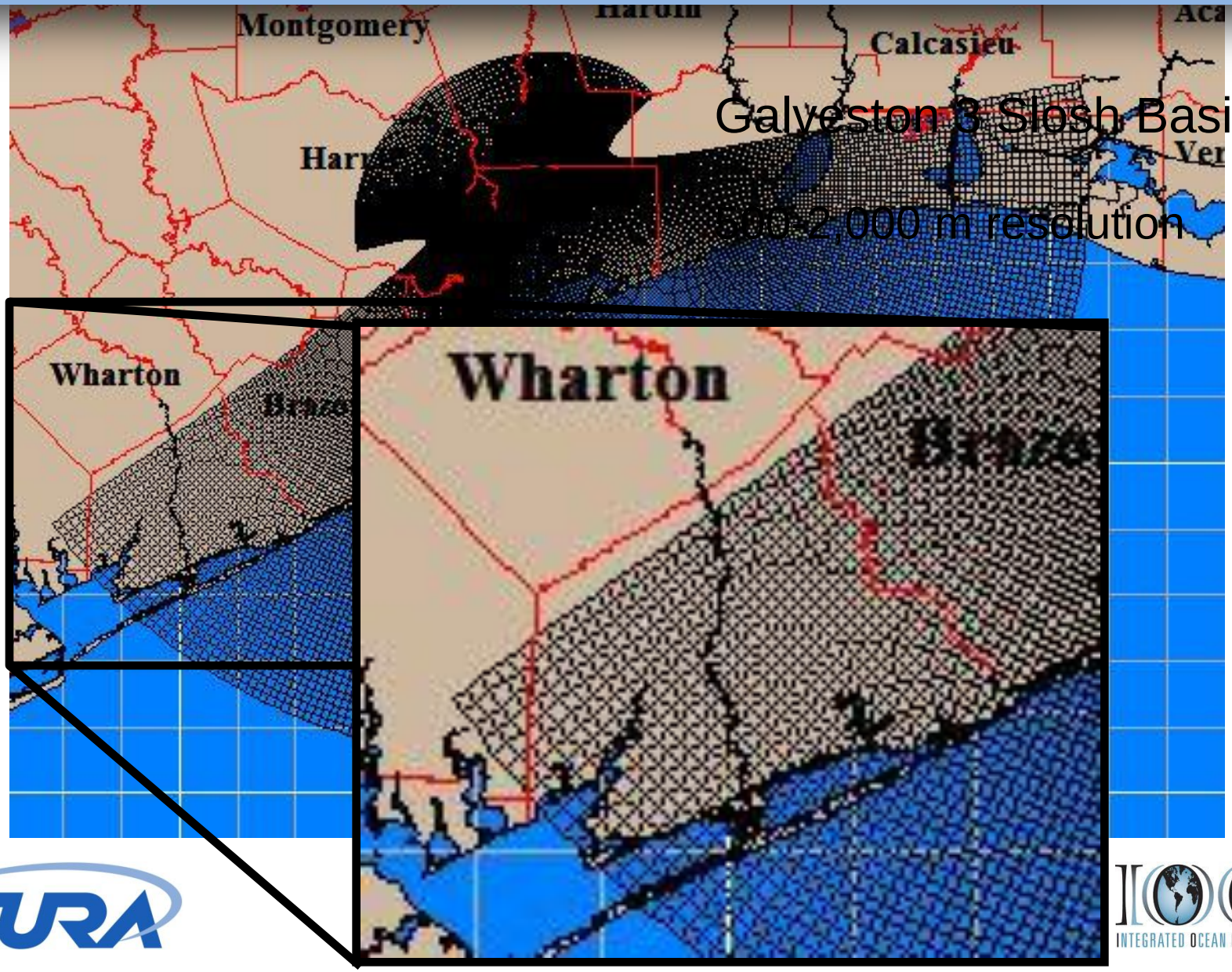
417,642 nodes



Gulf of Mexico SLOSH Grids



Gulf of Mexico SLOSH Grids



Galveston 3 Slosh Basin

500-2,000 m resolution

Gulf of Mexico SLOSH Grids

GoMx Extratropical Storm Surge

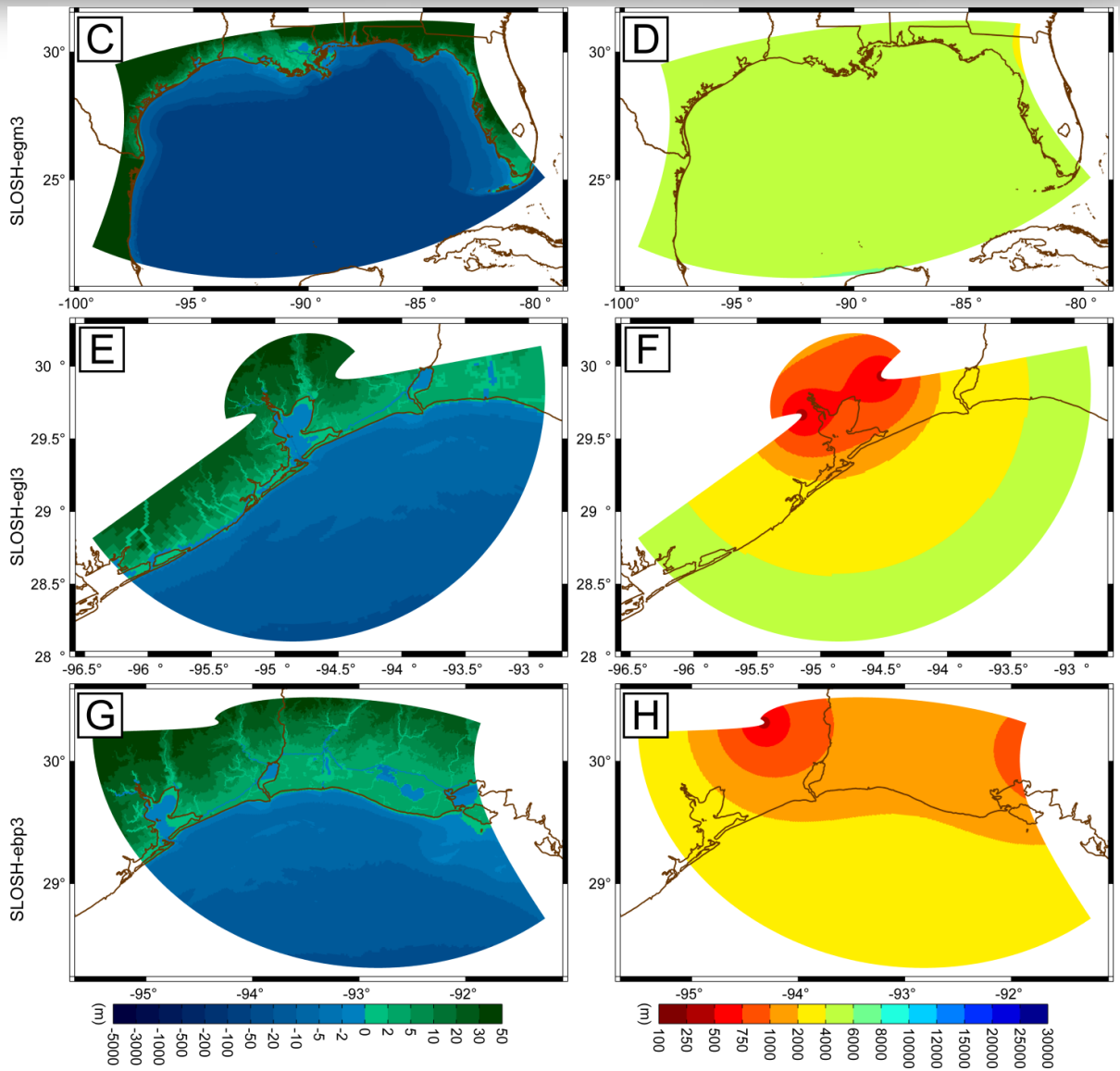
185,409 nodes

Galveston

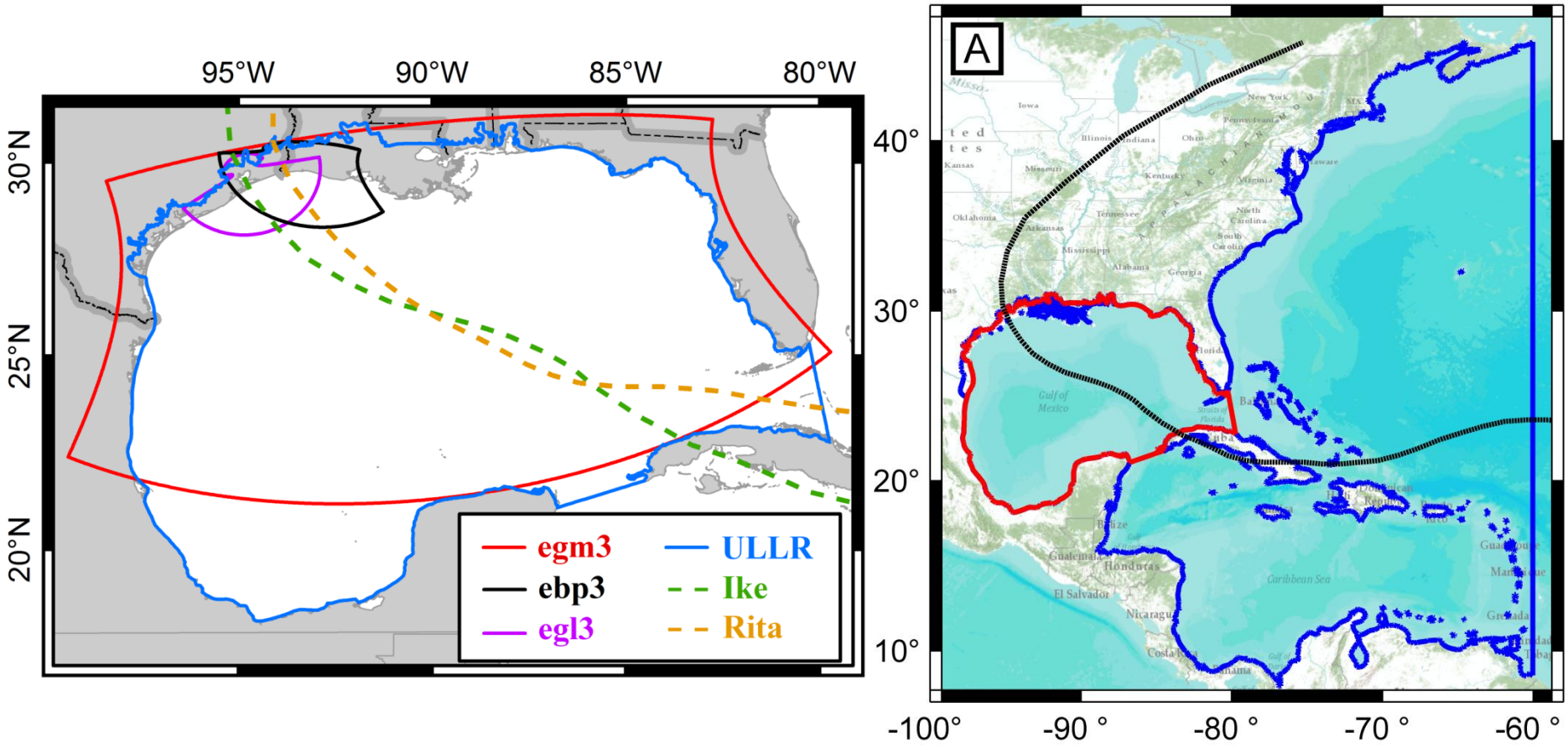
46,222 nodes

Sabine Pass

77,827 nodes

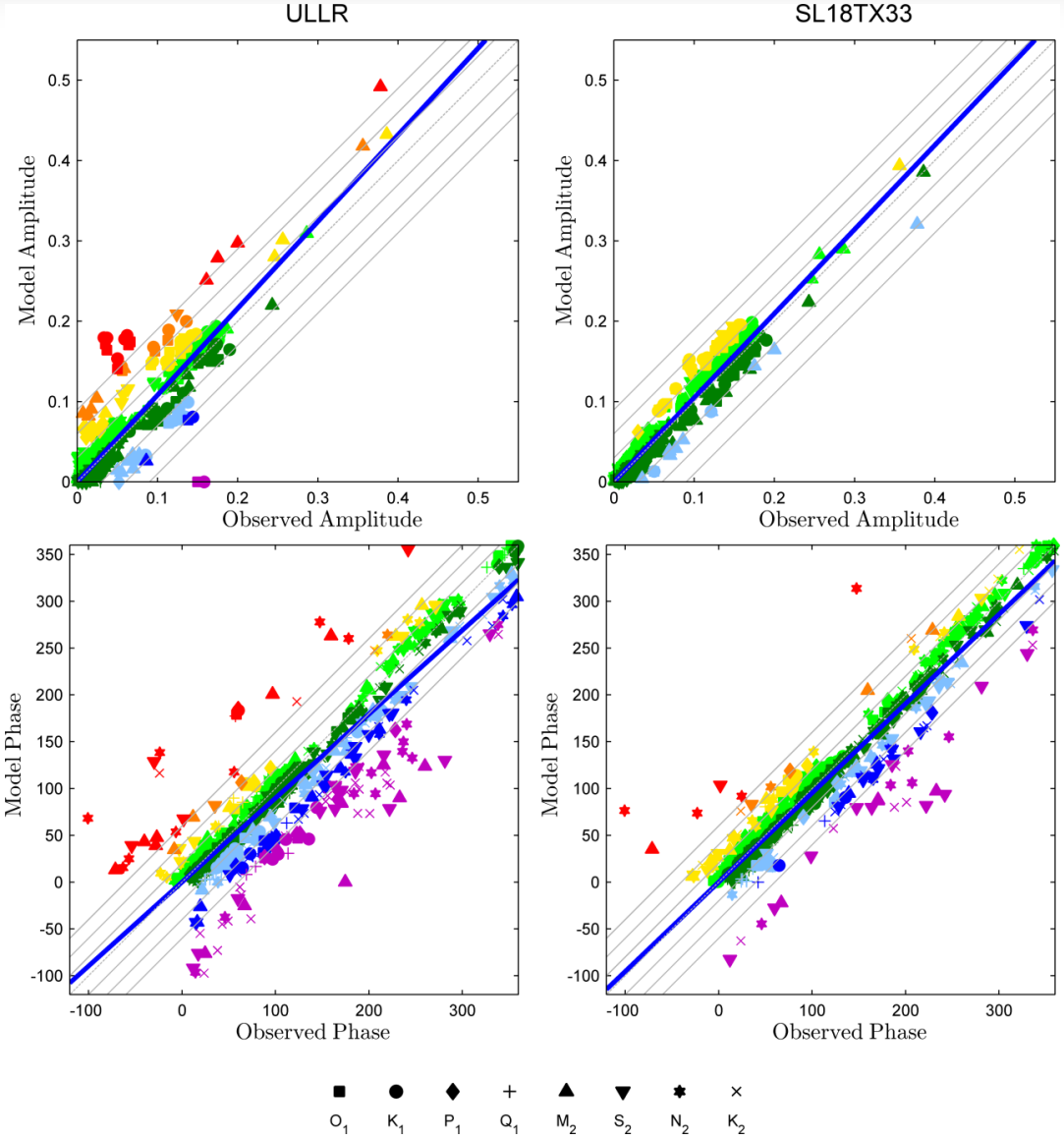


Gulf of Mexico Grids



egl3	egm3	ULLR	SL18TX33
46,222 nodes	185,409 nodes	417,642 nodes	9,228,245 nodes

Tides

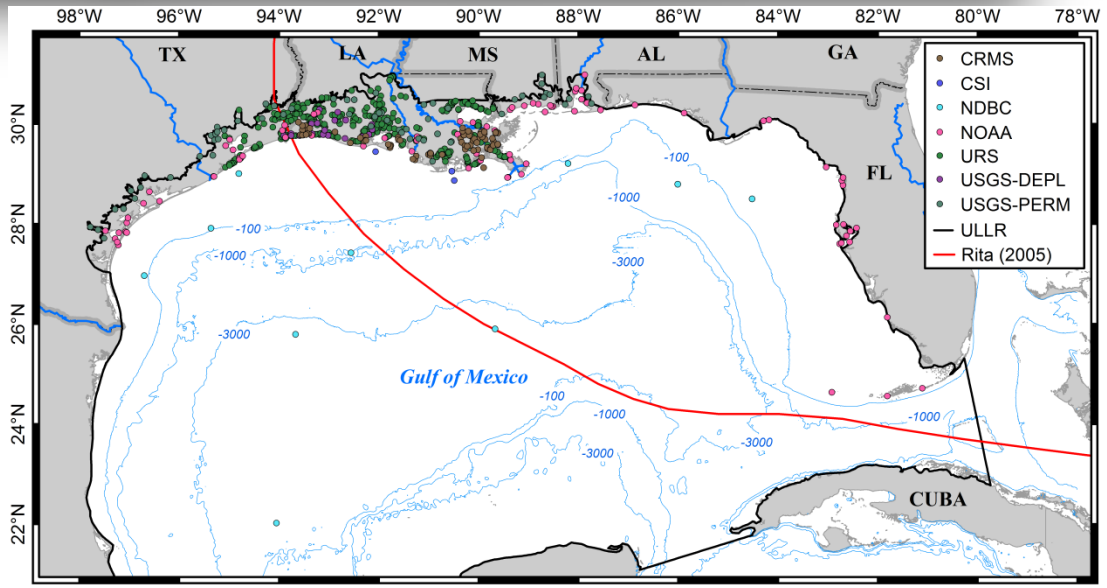

ULLR
SL18TX33
Model Amplitude
Observed Amplitude
Model Phase
Observed Phase
O1
K1
P1
Q1
M2
S2
N2
K2

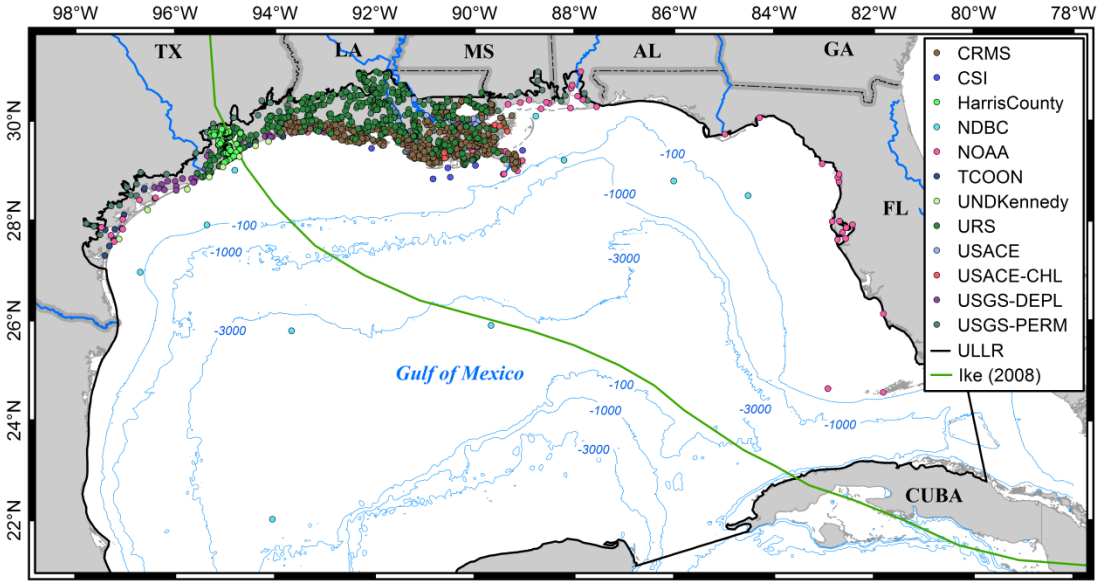
Waves/Surge/Inundation

Hurricane Rita (2005)

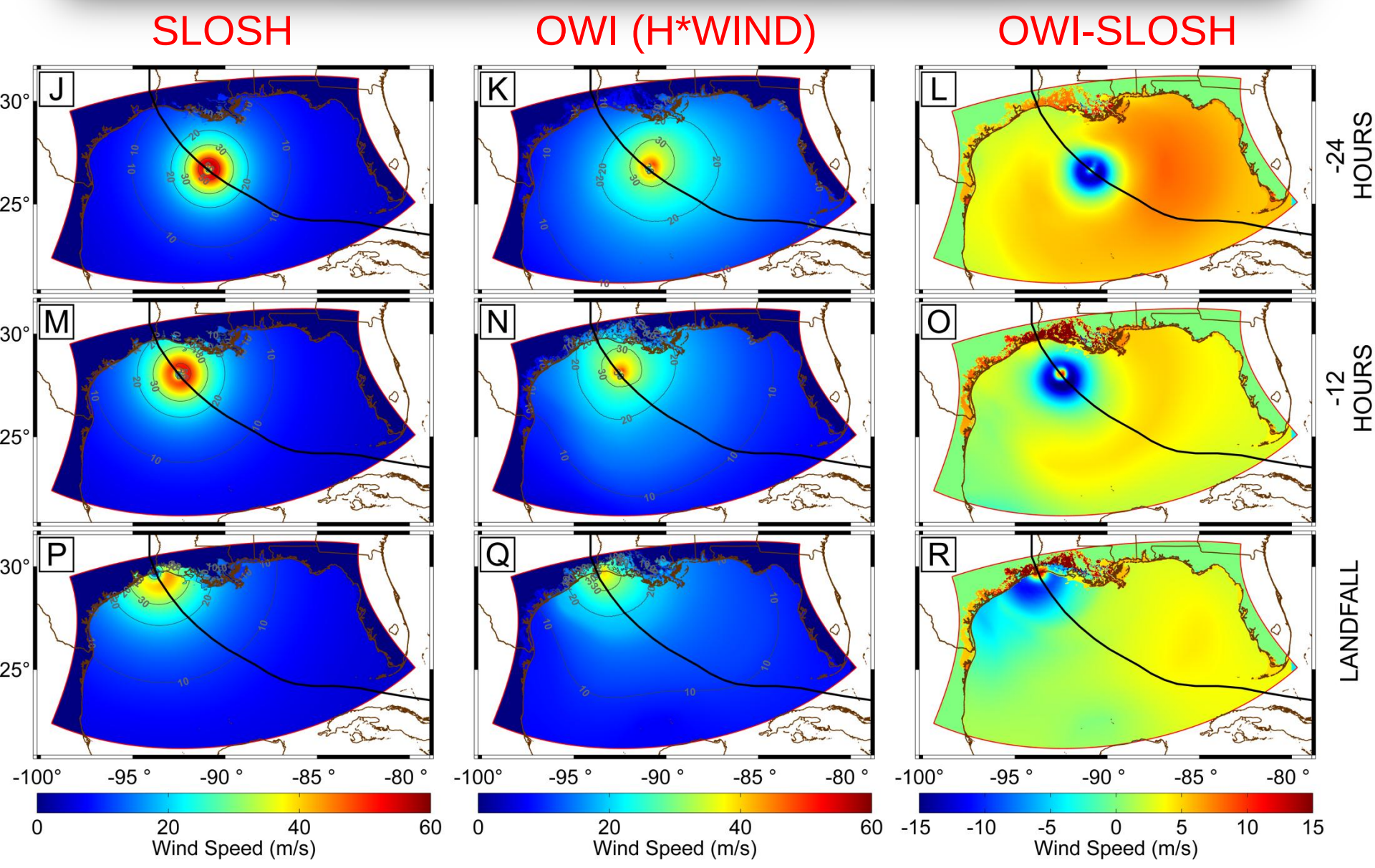
Tides
Hindcast H*WIND
Winds/Pressure

Hurricane Ike (2008)

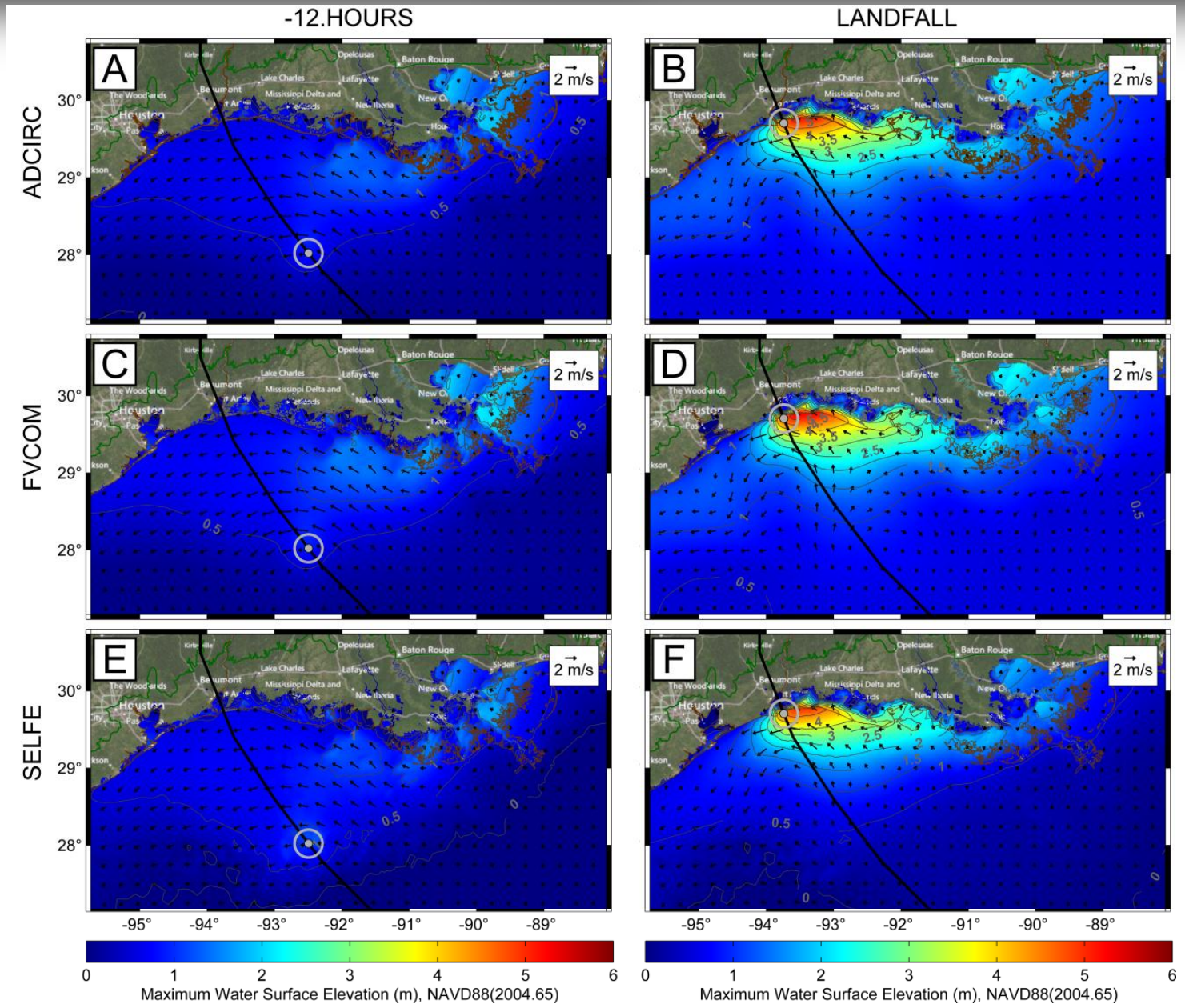




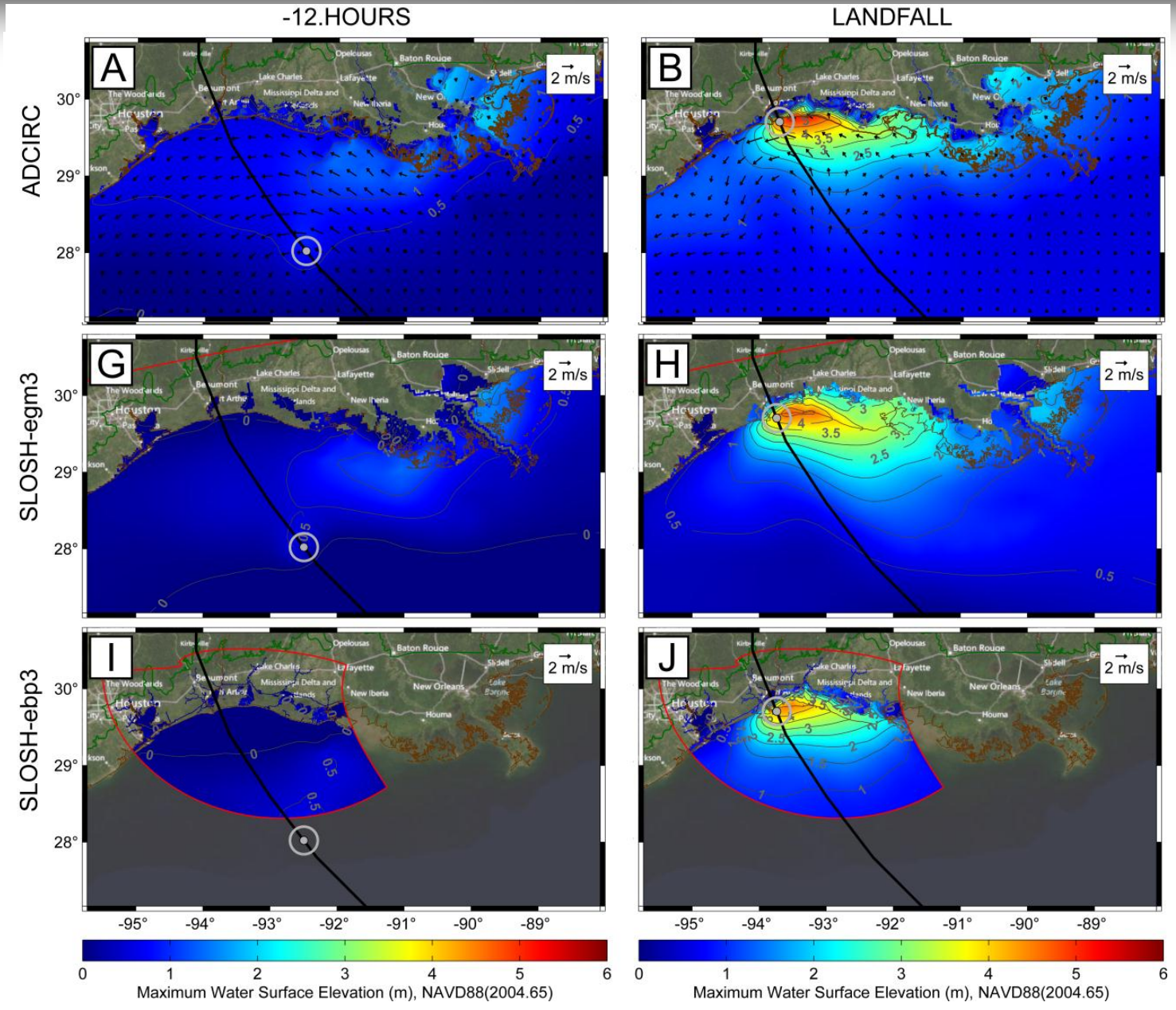
SLOSH Winds for Rita



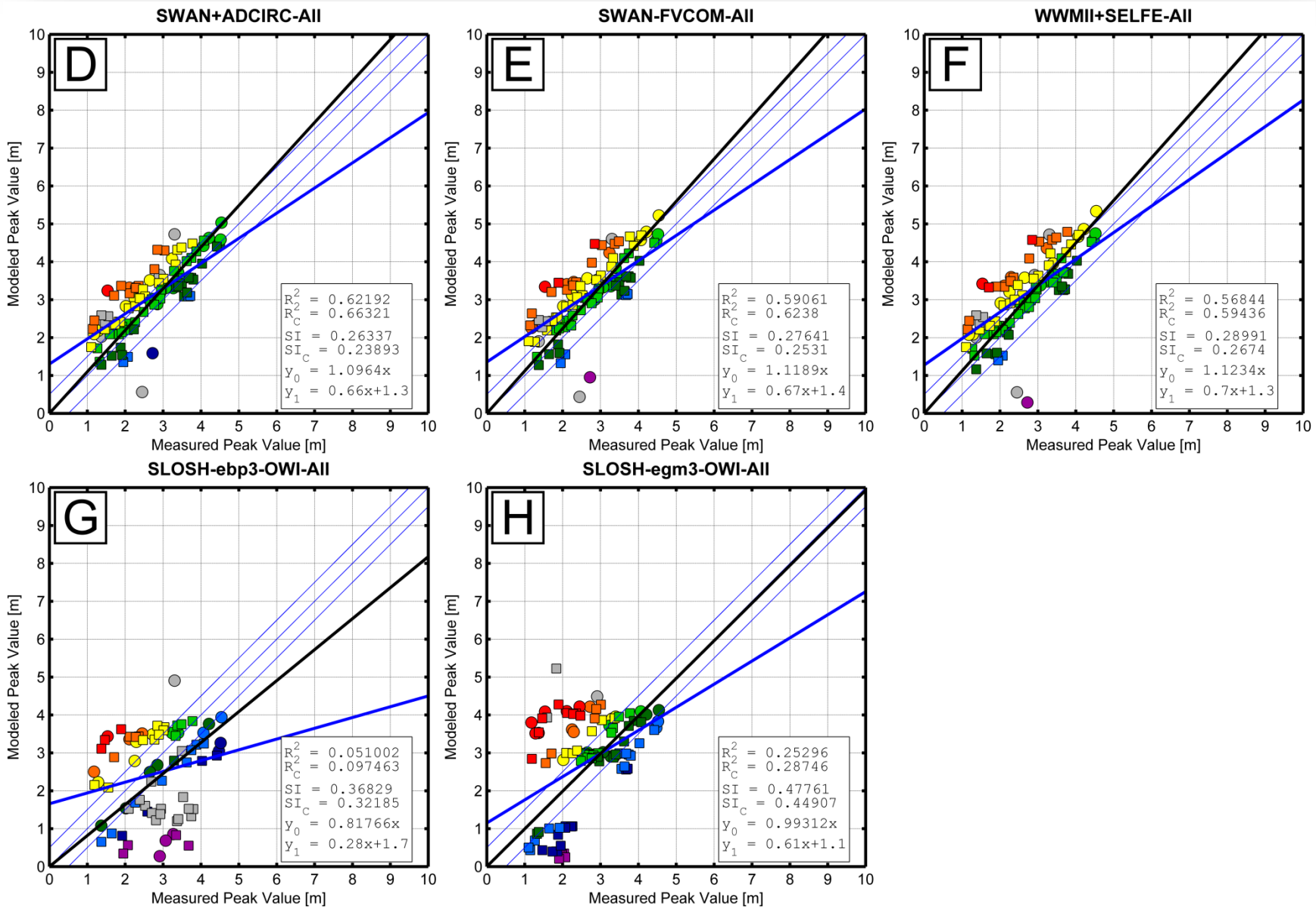
Rita


-12.HOURS
LANDFALL
ADCIRC
FVCOM
SELFE
A
B
C
D
E
F
2 m/s
30°
29°
28°
-95°
-94°
-93°
-92°
-91°
-90°
-89°
0
1
2
3
4
5
6
Maximum Water Surface Elevation (m), NAVD88(2004.65)
Maximum Water Surface Elevation (m), NAVD88(2004.65)

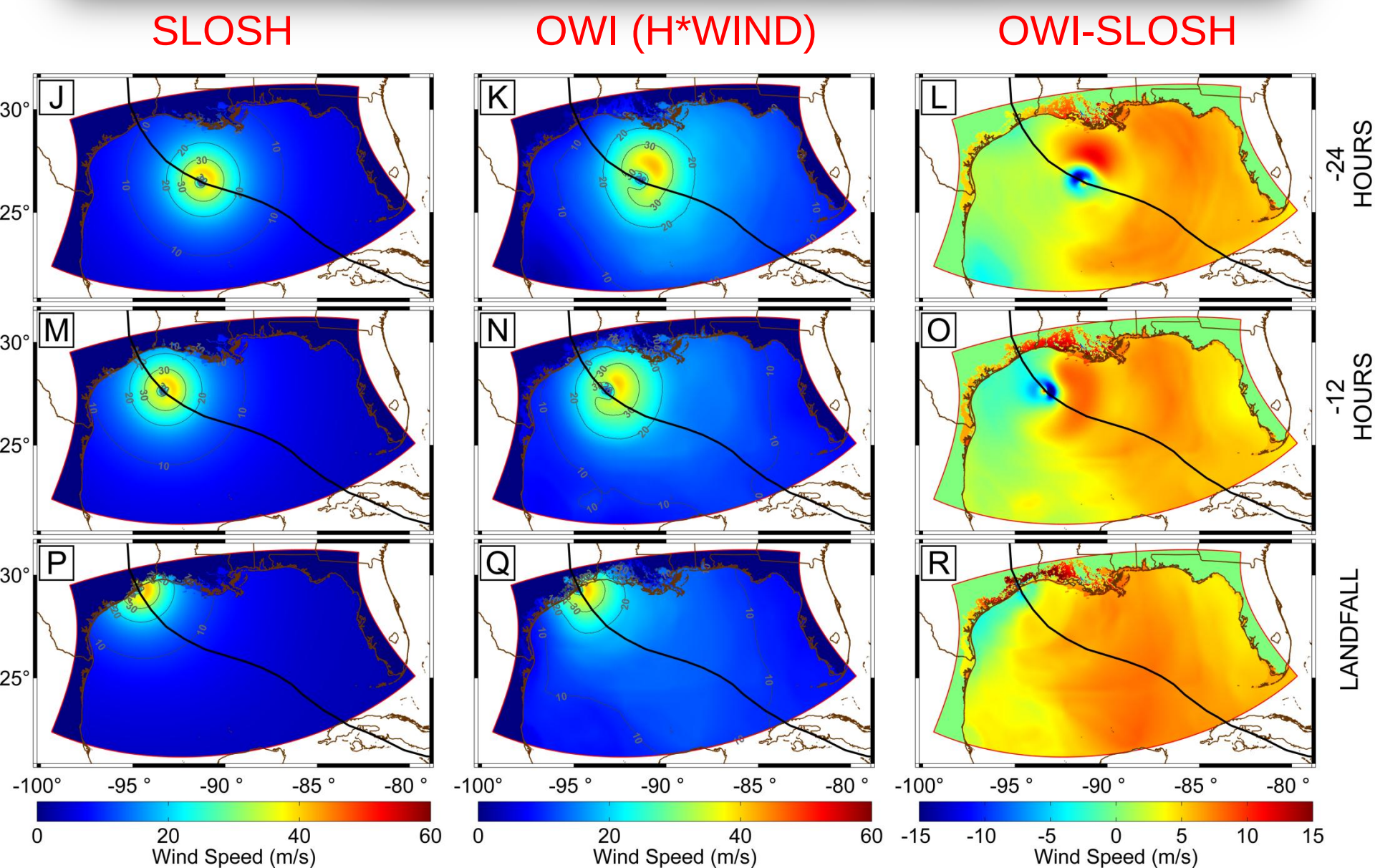
Rita


-12.HOURS
LANDFALL
ADCIRC
SLOSH-egm3
SLOSH-ebp3
A
B
G
H
I
J
2 m/s
30°
29°
28°
-95°
-94°
-93°
-92°
-91°
-90°
-89°
0
1
2
3
4
5
6
Maximum Water Surface Elevation (m), NAVD88(2004.65)
Maximum Water Surface Elevation (m), NAVD88(2004.65)

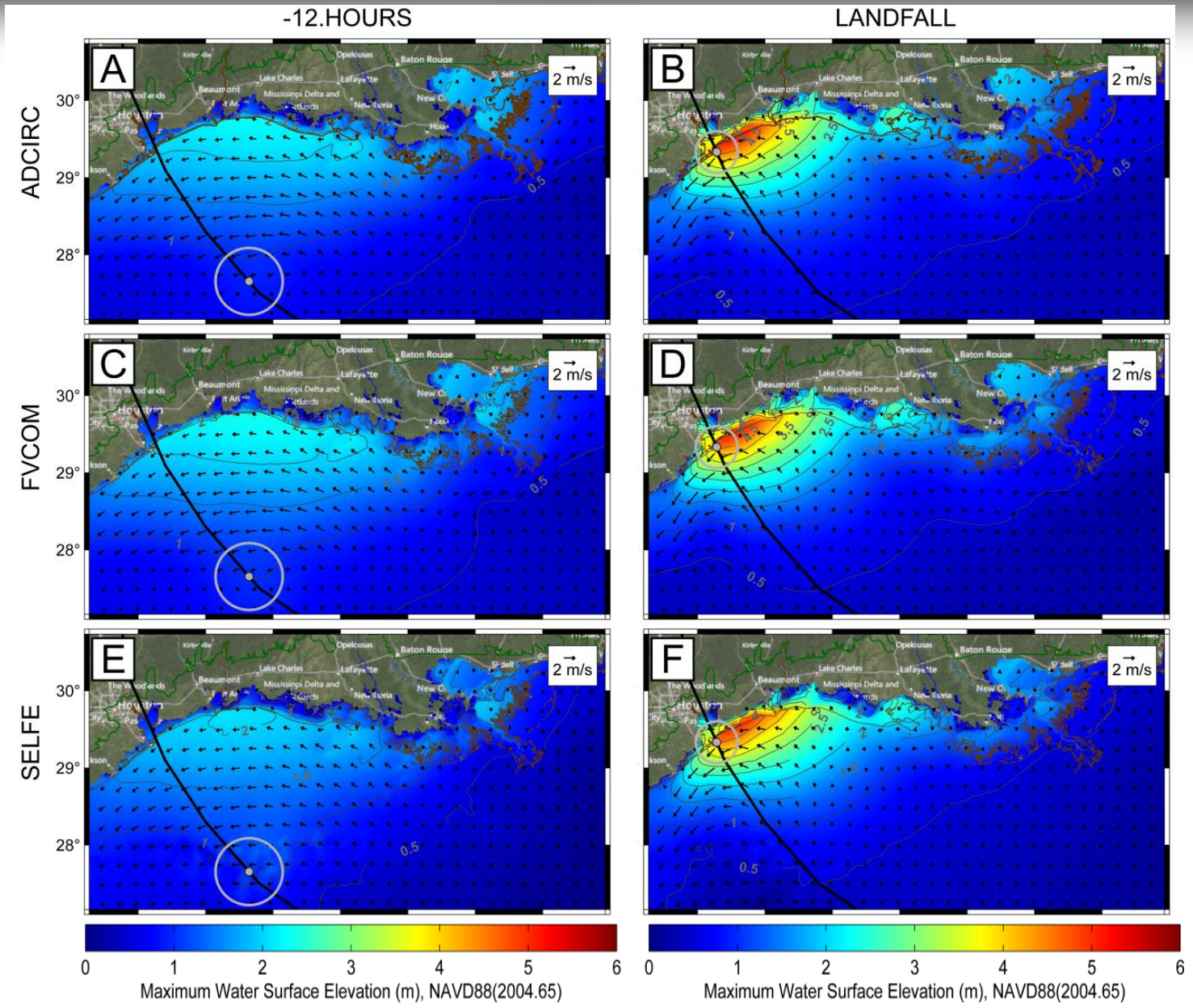
Rita


SWAN+ADCIRC-All
D
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.62192
R_C^2 = 0.66321
SI = 0.26337
SI_C = 0.23893
y_0 = 1.0964x
y_1 = 0.66x+1.3
SWAN-FVCOM-All
E
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.59061
R_C^2 = 0.6238
SI = 0.27641
SI_C = 0.2531
y_0 = 1.1189x
y_1 = 0.67x+1.4
WWMII+SELFE-All
F
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.56844
R_C^2 = 0.59436
SI = 0.28991
SI_C = 0.2674
y_0 = 1.1234x
y_1 = 0.7x+1.3
SLOSH-ebp3-OWI-All
G
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.051002
R_C^2 = 0.097463
SI = 0.36829
SI_C = 0.32185
y_0 = 0.81766x
y_1 = 0.28x+1.7
SLOSH-egm3-OWI-All
H
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.25296
R_C^2 = 0.28746
SI = 0.47761
SI_C = 0.44907
y_0 = 0.99312x
y_1 = 0.61x+1.1

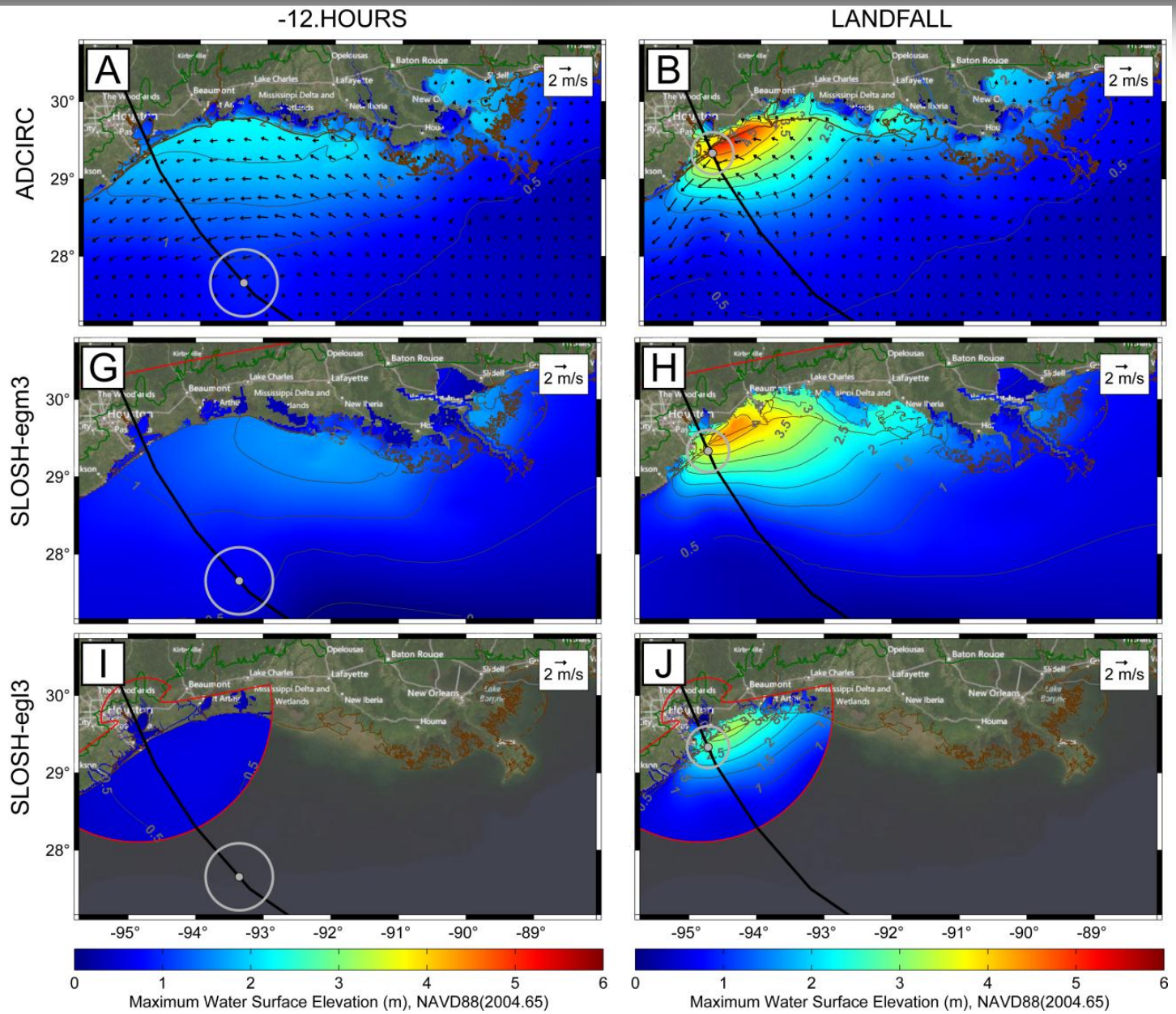
SLOSH Winds for Ike



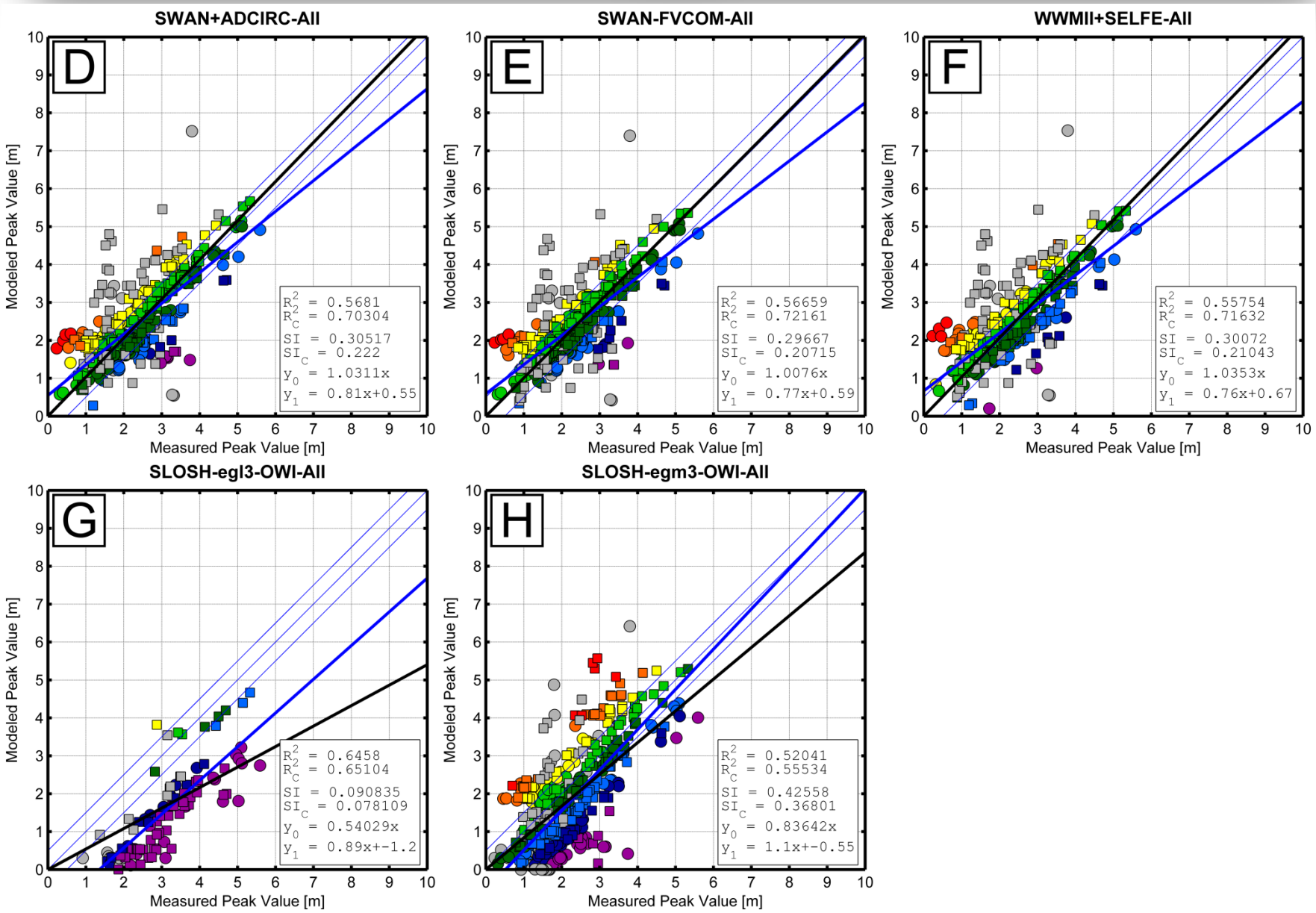
Ike


-12.HOURS
LANDFALL
ADCIRC
FVCOM
SELFE
A
B
C
D
E
F
2 m/s
30°
29°
28°
Opelousas
Baton Rouge
Lake Charles
Lafayette
Beaumont
Houston
New Orleans
0
1
2
3
4
5
6
Maximum Water Surface Elevation (m), NAVD88(2004.65)

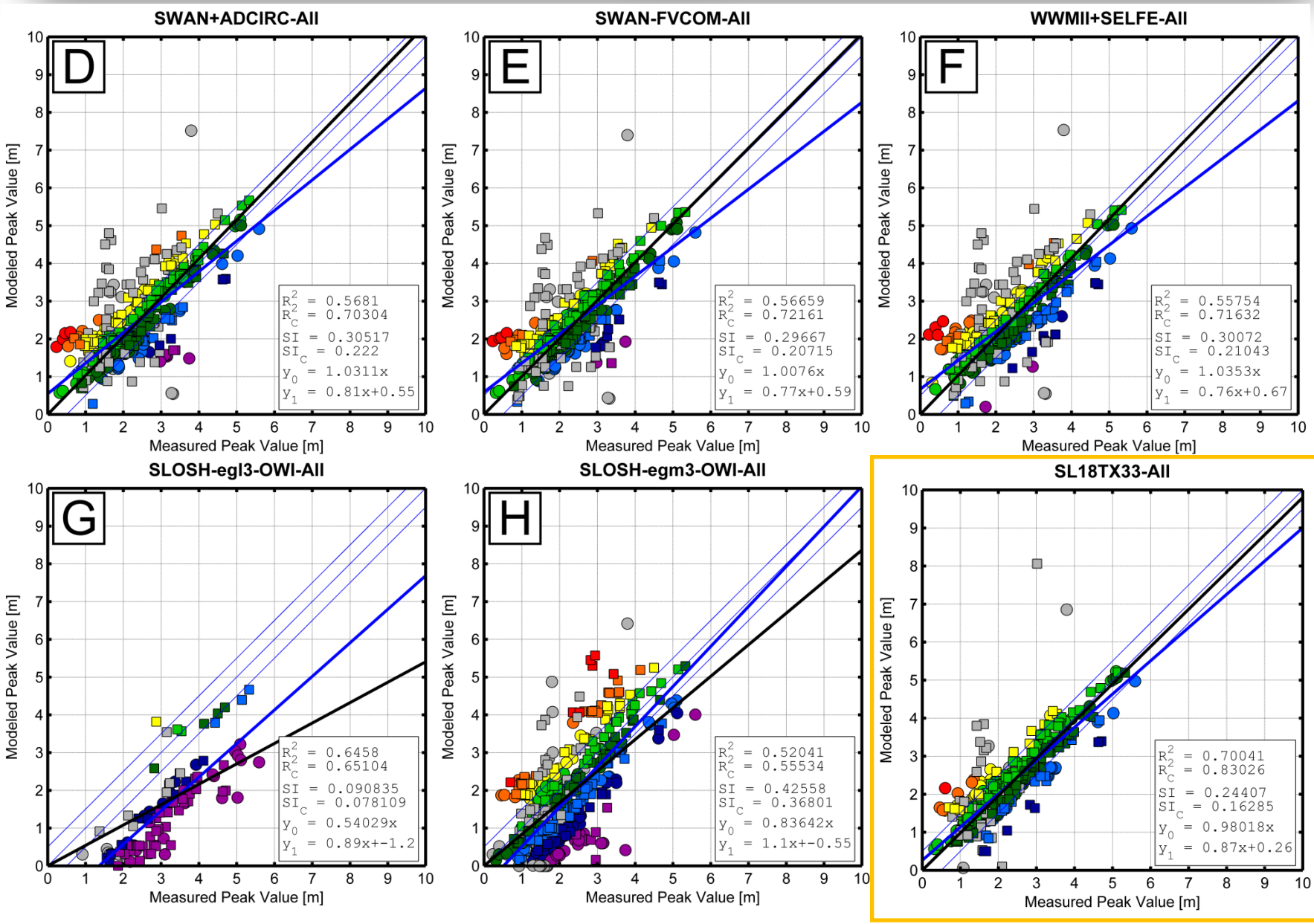
Ike


-12.HOURS
LANDFALL
ADCIRC
SLOSH-egm3
SLOSH-egl3
A
B
G
H
I
J
2 m/s
Opelousas
Baton Rouge
Lake Charles
Lafayette
Beaumont
New Iberia
New Orleans
Houma
30°
29°
28°
-95°
-94°
-93°
-92°
-91°
-90°
-89°
0
1
2
3
4
5
6
Maximum Water Surface Elevation (m), NAVD88(2004.65)

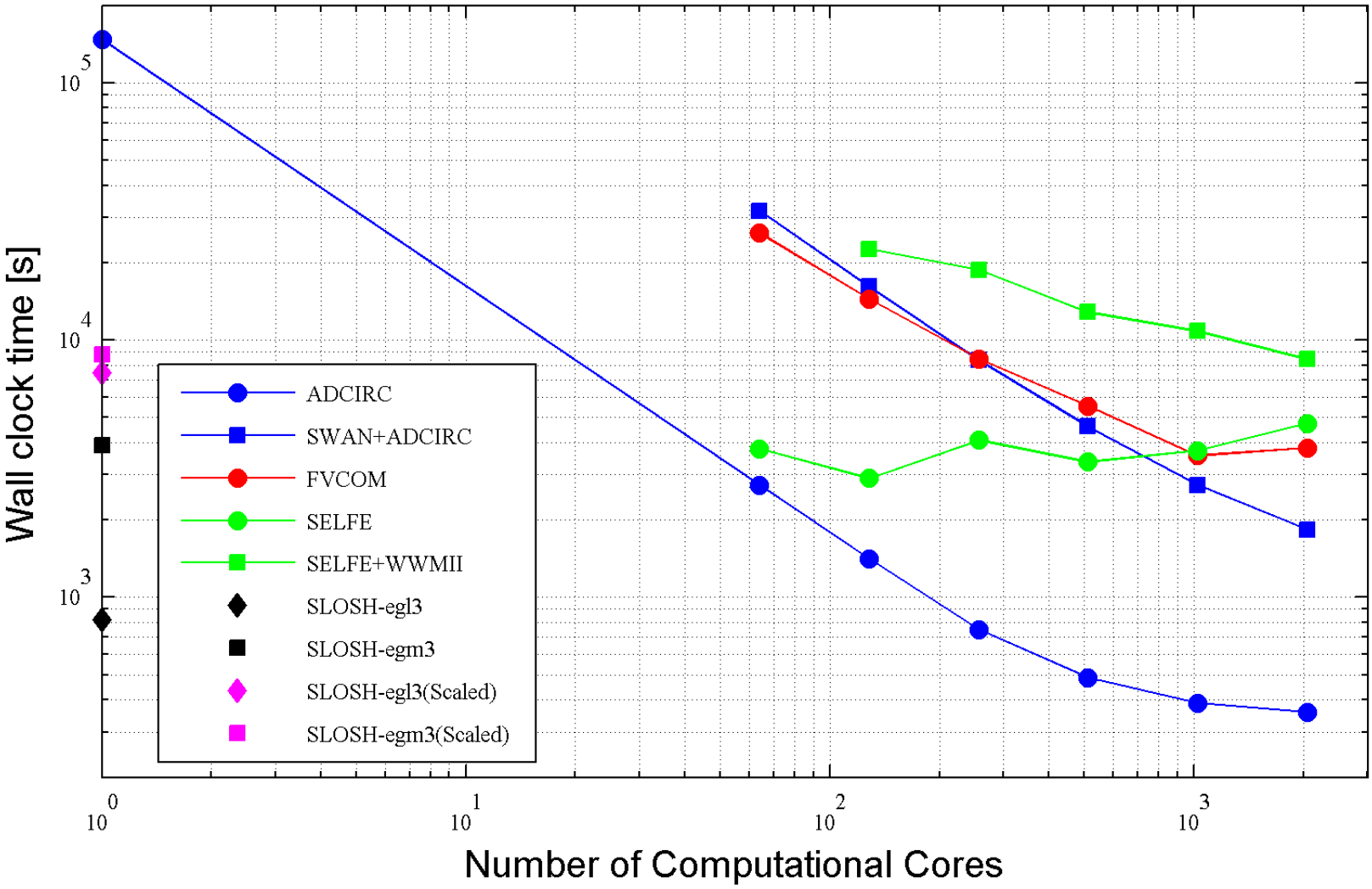
Ike


SWAN+ADCIRC-All
D
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.5681
R_C^2 = 0.70304
SI = 0.30517
SI_C = 0.222
y_0 = 1.0311x
y_1 = 0.81x+0.55
SWAN-FVCOM-All
E
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.56659
R_C^2 = 0.72161
SI = 0.29667
SI_C = 0.20715
y_0 = 1.0076x
y_1 = 0.77x+0.59
WWMII+SELFE-All
F
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.55754
R_C^2 = 0.71632
SI = 0.30072
SI_C = 0.21043
y_0 = 1.0353x
y_1 = 0.76x+0.67
SLOSH-egl3-OWI-All
G
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.6458
R_C^2 = 0.65104
SI = 0.090835
SI_C = 0.078109
y_0 = 0.54029x
y_1 = 0.89x+-1.2
SLOSH-egm3-OWI-All
H
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.52041
R_C^2 = 0.55534
SI = 0.42558
SI_C = 0.36801
y_0 = 0.83642x
y_1 = 1.1x+-0.55

Ike


SWAN+ADCIRC-All
D
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.5681
R_C^2 = 0.70304
SI = 0.30517
SI_C = 0.222
y_0 = 1.0311x
y_1 = 0.81x+0.55
SWAN-FVCOM-All
E
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.56659
R_C^2 = 0.72161
SI = 0.29667
SI_C = 0.20715
y_0 = 1.0076x
y_1 = 0.77x+0.59
WWMII+SELFE-All
F
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.55754
R_C^2 = 0.71632
SI = 0.30072
SI_C = 0.21043
y_0 = 1.0353x
y_1 = 0.76x+0.67
SLOSH-egl3-OWI-All
G
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.6458
R_C^2 = 0.65104
SI = 0.090835
SI_C = 0.078109
y_0 = 0.54029x
y_1 = 0.89x+-1.2
SLOSH-egm3-OWI-All
H
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.52041
R_C^2 = 0.55534
SI = 0.42558
SI_C = 0.36801
y_0 = 0.83642x
y_1 = 1.1x+-0.55
SL18TX33-All
Modeled Peak Value [m]
Measured Peak Value [m]
R^2 = 0.70041
R_C^2 = 0.83026
SI = 0.24407
SI_C = 0.16285
y_0 = 0.98018x
y_1 = 0.87x+0.26

Run Time Performance - Hurricane Ike



Conclusions

- SLOSH Sensitivity
  - Substantial bias in small basin results
    - may be difficult to anticipate
    - is not “corrected” via ensembles
    - *Size matters*
  - Large domain / high resolution deterministic runs valuable for evaluating small basin performance for any given storm
  - Internal wind model overestimates inner storm cell and under-estimates far field velocities compared to data-assimilated winds.

Conclusions

- Inter-Model Comparison
  - The unstructured models all performed similarly and accurately and were more accurate than SLOSH, which failed to develop a strong ‘forerunner’ for Ike.
  - SLOSH is much faster than other tested models allowing ensemble-based probabilistic predictions
  - High-resolution is very important for:
    1. Capturing tides, especially in inland areas.
    2. Effectively conveying coastal inundation and capturing fine-scale features such as levees and channels.